# Abstract:

Over the years teachers have had the consistent struggle of trying to get across a concept, especially in Computer Science and engineering, which would be better explained if the discussed object was in front of the whole class for the teacher to assemble, disassemble and reference to first hand in a way that is inherently more understandable and engaging to students.

The project will be an application that uses augmented reality and tangible objects to explain how robotic components work independently and with each other. The app will allow to zoom in on different layers to see the interaction between different modules or between different components on one module or to show the functionality within a single component. This will result in a better understanding for the user of complex robotic architectures which will allow the user to better visualize it and will in turn help the user to be further able in using this tool for robotics.

# Acknowledgements:

# I want to thank my parents for giving me the opportunity to attend the school and gain such knowledge, I want to thank them for always pushing me to work hard and achieve what they knew I could. I feel very lucky to be at this point in my education as if it weren’t for their support and love I would not have been able to achieve my goal in my education. I would also like to thank my friends for always giving me their support throughout the journey of this degree, I would like to thank the friends and family who have always been there to give me support and words of wisdom. Were it not for these people I would not have made it to where I am today through sheer will power alone but thanks to them all I feel proud to give this dissertation as the accumulation of my education. Thank you.

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# Keywords:

Augmented Reality, Robotics, Higher Education, AR, Teaching

# Introduction:

Today, schooling is very much of the same thing no matter where one attends and in terms of robotics this is observable through the fact that nobody gets real components right away. A lot of the time labs and lectures are used to teach students on how to handle and use robotic components, however, these can be inaccurate or confusing and students still run into multiple problems once they start to work with the real thing. For these reasons, augmented reality in the classroom would be ideal where the teacher can demonstrate and pass around real components and students can interact with them without ever plugging them in(Gupta, 2017). the application will help students understand transferring of data, pin locations, components, short code for components, etc.

A common issue found in schooling is that many students find themselves not understanding practical concepts through a verbal information passing method which is the most common way schools try to teach. The application uses augmented reality in an attempt to better explain complex robotic architectures and information regarding components and how to make them work to the user. This method takes extensive advantage of all the different methods in which a human learns information in an attempt to pass information in a more effective way so that students better understand the workings of the components shown thus minimising the basic mistakes one makes when starting out with learning robotics.

# Background and Literature Review:

In the field of augmented reality, the current material already available can be found in every aspect of our day to day lives, this can be confirmed by realizing that such things like augmented reality interactive white boards and games for children exist as well as heads up displays in cars and augmented reality assisted surgery(Dickey *et al.*, 2015). The most promising of the above-mentioned fields where AR is integrated is without a doubt education where through visualizing material many topics and concepts can be delivered in a faster and more well-defined way for both student and teacher, this becomes clear when looking at the amount of research done on the topic in that field where there are papers ranging from using augmented reality to teach the differently abled to better their social school and work lives(Brain Power, 11AD) to tangible user interface which are augmented over to teach in schools. As previously mentioned the idea will integrate itself in a more challenging aspect of education which will be degree level robotics where through augmentation of components the lecturer would be able to demonstrate on them as well as pass them around the class without having them connected to electricity, thus because of the nature of the material to be taught certain techniques that invoke attention and learning such as certain color schemes that invoke attention as well as using the sound and vibration that the phone offers to further immerse the student into the learning process(Mike Parkinson, no date).

## 2.1 History

Tangible augmented reality has been the topic of many debates in the past 50 years which is when the technology at the time began to support this concept. Today we know that this technology could be used in any way imaginable but is most commonly know to be used for its exceptional affinity for passing learning material in a more excepting way. In the past studies have shown that having an interactable object to use whilst learning is more effective than putting students in a classroom for hours and having them sit through information being fed to them to memorize and learn as in many cases the problem with passing information is not that it is hard to grasp as it is to engage the student in a way where they will absorb all the information given to them. Using tangible models has been found to be effective in the further teaching of a concept rather than presenting a concept for the first time whilst using augmented reality was useful for taking the learning even further than that by using moving animations as well as static ones which can be more effective for explaining things that small models cannot(Chen *et al.*, 2011). We can also see that tangible augmented reality is a better approach to the main goal that augmented reality in general was created to achieve which would be to bridge computer entertainment back to the real world (Magerkurth *et al.*, 2005), this can be considered true because of the fact that if bridging the digital world with the real world is the goal of augmented reality, adding another dimension, which is the tangible aspect, brings us closer to the fuller realization of that goal. The most recent solution to this problem is being done with tangible user interfaces (TUI) and motion and gesture tracking devices so that interaction with real-world tangible objects can be detected and software can then react accordingly, an example of this is a table-top TUI made to play chess against a virtual opponent where real-world pieces on the users side are moved but augmented pieces on the opponents side move accordingly in a game of chess(Rayar, Boas and Patrizio, 2015). Tangible augmented reality has been found to also work in heightening an immersive experience, this is due to the fact that the experience doesn’t need to compensate for immersing the user into a world as he/she are still fully immersed in the real world as always. The experience is better explained as tweaking and altering real life in a desired way where through the user’s perspective the world becomes interactable, a good example of this is google glass (Glass X) where the glasses augment data, notifications, feedback, share live video of what is seen, make searches on the fly hands-free, etc. over the real world to provide the user with a digitally interactable real world(*Glass*, no date).

## 2.2 Augmented Reality

According to Dunleavy, Dede, and Mitchell (2009, p. 20), AR's most significant advantage is its “unique ability to create immersive hybrid learning environments that combine digital and physical objects, thereby facilitating the development of processing skills such as critical thinking, problem solving, and communicating through interdependent collaborative exercises.”. as previously mentioned Augmented reality and tangible augmented reality have both significant benefits to education in terms of absorbing material and helping in the understanding of labs however there have been studies that mention the drawbacks with augmented reality. One of these drawbacks, for instance, is that augmented reality can be buggy as well as complicated for students to grasp the functionality without an efficient UI or assistance(Lin *et al.*, 2011), another might be the requirements that would be necessary for an augmented reality system to work, which would be (Bower *et al.*, 2013):

* The presence of a camera to capture live images
* Significant storage space for virtual objects
* a powerful processor to either composite virtual and real objects or display a 3D simulated environment in real-time
* an interface that allows the user to interact with both real and virtual objects.

Albeit that augmented reality does have its flaws their impact can be lessened through enhancements to the system such as (Bower *et al.*, 2013):

* GPS Technology – allows the system to take into account the user’s real-world location, ensuring that contextually relevant virtual data is provided to the user at geographically significant locations.
* Image Recognition Software – enables real world images and objects to act as ‘triggers’ for multimedia and model overlays, and also to anchor virtual data in the environment.
* Speakers and Sound Systems – enables relevant sounds and audio recordings to be played.
* Internet Access – provides a means of storing, retrieving and sharing content using social media and Web 2.0 technologies.
* Intuitive Interfaces – advances in touch screen, gyroscope, and haptic input technologies provide

Besides the above-mentioned points that help augmented reality lessen the drawbacks, adding tangible objects to augmented reality will make the system more user friendly as it is easier for people to interact with real- world objects as it is second nature than to use any type of UI.

## 2.3 Existing Technologies in Augmented Reality

The tangible augmented reality system that will be implemented in this project is projected to be capable of teaching students in a comprehensible way which will also help them in absorbing the information provided, this is not meant to be a solo learning experience rather than it being a learning tool to be used in a lecture where material will be delivered by the lecturer whilst he/she will reference to the things seen on the application. The helpfulness of the tool comes in where the student will be able to see the flow of data and electricity augmented over the wires, tagged names of different components, augmented activity of different components as well as recommended code for detected components to work in the real-world. An example of a similar study done is “An Empirical Study on Tangible Augmented Reality Learning Space for Design Skill Transfer” where a prototype on the framework developed was used to examine how tangible augmented reality systems can help design learning experiences. In this prototype square marker patterns have been used to present multi buildings which provide the functionality of extendable marker collection. The TAR system although, as with all things, came with its inherent flaws proved to be better at detailing in texture and visualization which increases the perception from the reflective observation as well as being more convenient as there was less to carry than more conventional methods(Chen and Wang, 2008). The heart of this project will be the Unity game engine which has impeccable functionality for augmented and virtual reality environments to be created. The Unity game engine will be what keeps the different aspects working in harmony with each other to produce the finished product which consists of creating virtual objects that will be augmented over the real world as well as creating a functional UI and coordination with the Vuforia library to use the camera to detect objects and their orientation to use the according virtual objects(Nguyen and Dang, 2017). In many similar projects to this one, studies have shown that the augmented tangible models were quite engaging and instructive with students in school, however, a lot of the time a more comprehensive lesson plan created specifically to be used with the tangible augmented reality needs to be created in order for it to be more effective(Gillet *et al.*, 2004).

Aside from education we can see augmented reality having many different benefits to multiple fields of work and study where, in a different variation of its application, can be a tool that makes ground breaking differences in the modern work and entertainment world. One may see examples of these different applications of augmented reality in manufacturing and engineering where workers can now use augmented reality to load up manuals, tutorial videos or order parts all on the fly(*What Can Augmented Reality Do for Manufacturing? &gt; ENGINEERING.com*, no date) as well as in the entertainment industry where augmented reality video games and other entertainment systems such as TVs are growing in popularity and interest.

## 2.4 Tangible Augmented Reality

The tangible aspect in TAR is a crucial turning point where augmented reality evolves into a better version of itself as it further reaches its goal to join the real and virtual world through adding a new dimension to the experience. Many might argue why a tangible approach instead of any other, this question can be answered through observations in human behavior where its obvious that using our hands to interact with real world objects comes naturally. Examples of this type of interaction can be seen in tangible user interfaces (TUIs) where different methods of execution of it have made it into a category of interaction of its own. One of the methods of TUI’s implementation is as a table top tangible user interface where the user interacts with a UI displayed atop a table using tangible objects that are captured by a camera from either inside or outside the table. A few examples of this method would be the Tabletop Tangible User Interface Specification Model (TTUI-SM) which was created aiming to support every interaction possibilities of the tabletop tangible interfaces, be it a gesture interaction or a physical object interaction (Dourado, Botega and Araújo, 2014), another example of TUIs is The reacTable, a collaborative musical instrument is used to create music by placing tangible models on a tabletop, this can be done by one person or many people whilst being a learning experience about musical control and manipulation. This idea can be ideal for the experimental exploration of novel forms of human-computer-interaction for a number of reasons (Kaltenbrunner *et al.*, 2006):

* It is an environment that combines outstandingly, expression and creativity with entertainment; freedom with precision, rigor and efficiency
* Users are required to have an open but precise and rather complex control over multi-parametric processes in real-time.
* Playing and creating music with the help of digital tools can be a social and collective experience that integrates both collaboration and competition. Moreover, this experience can also be addressed to children.
* Music performance provides an ideal test bed for studying and comparing use and interaction by both dilettantes and experts, both children and adults.

In recent studies on TUIs we can see that they are gaining rapid popularity in Education and learning where many are seeing their potential for engaging students to learn a concept, once again the lesson plan as well as the UI of the TUI must be tailored to teach something specific in a way where they can complement each other. Another table top TUI would be a project that used Tangible tiles that implements tiles detected by a camera that contain and are associated with certain data that is then displayed on the interface, through these tiles information, images, videos, etc. can be played thus this can be used for education and interactive tasks in a range of ways (Waldner *et al.*, 2006). Another method of TUI is through games where tangible object are used as controllers, this has been well executed by Tangibot, A tangible-mediated robot to support cognitive games for ageing people. Tangibot is a TUI prototype in the form of a mobile robot controlled by physical paddles aiming at creating games for the elderly to train their cognitive abilities. The proposal consists of a generic and versatile technological device that allows both the elderly and the game designers (therapists) to easily create a range of activities. It also enables natural interactions through tangible manipulations and has the potential to foster socialization and the training of cognitive abilities that can improve the elders’ quality of life(Garcia-Sanjuan, Jaen and Nacher, 2017). It is evident that tangible user interfaces can be implemented in any area of learning when specified with a particular topic to teach and whilst they have their draw backs they have the potential to be a vital tool in improving the schooling system as well as piquing the interest of the future generation in technology as well as any subject presented which will evidently contribute to human progression. A final example of the great learning capabilities of TUIs is the BeatTable a learning environment that builds upon learners' previous conceptions in the domain of rhythm and proportion in order for them to learn those concepts. The BeatTable is a learner-centered microworld for exploring musical and mathematical concepts(Bumbacher *et al.*, 2013).

Once we introduce the benefits of the above mentioned tangible user interface to the notion of augmented reality the resulting development is Tangible augmented reality, an environment with limitless possibilities for interactions and molding to specified scenarios in whatever field of interest need. A perfect example of the accumulation of the two systems is the TARBoard a Tangible Augmented Reality System for Table-top Game Environment, the objective of TARBoard system is to let users fashion the board or card game in a more interactive and intuitive way. The setup allows for augmented reality makes the game more realistic and interactive and tangible user interface enables users to interact with virtual objects in the game intuitively. As a result of this matchup the virtual world can be brought out of the computer and immerse the user in an experience that digitally shows visuals whilst having an intuitive interactivity system which provides an immersive and easy to use system (Lee, Woo and Lee, 2005). A similar project to this one proves the learning capabilities of tangible augmented reality in the field of mechanics, the Automatic Zooming Interface for Tangible Augmented Reality Applications an automatic zooming method that helps users to achieve a closer view to the scene without losing tracking. By up- dating the zoom factor based on the distance between the viewpoint and the target object, a natural and intuitive zooming interaction is achieved. By overlaying computer graphics image on top of live video stream and showing the virtual scene registered to the real world, the AR provides natural views of 3D virtual objects such as CAD (Computer Aided Design) models and allows the user to zoom and interact with them (Lee, Bai and Billinghurst, 2012).

## 2.5 Benefits of the Technology

The benefit of the above-mentioned accumulation of technologies in education are the further progression towards a better recognized method of schooling that can be integrated into schools, this method being a better way of teaching students within a line of work that requires a certain expertise and practical knowledge rather than giving them text book schooling where they will then have little to no real experience when joining the workforce. Educators know that a student learns more quickly and retains more information when the subject matter pertains to them personally. The act of *doing* makes learning extremely personal. As Sir Richard Branson says, “You don't learn to walk by following rules. You learn by doing, and by falling over.” The process of experiential learning involves both self-initiative and self-assessment, as well as hands-on activity (Envision, 2015. The Benefits of Experiential Learning. Envision.).

This project could further prove the benefits of tangible augmented reality and its serious need to be implemented in our schooling system, if successful the application will deliver material seamlessly through an intuitive and entertaining learning experience which will trigger the further interest of students in the field. As one can see from the above document the two fields of tangible user interfaces and augmented reality go hand in hand to create new experiences that fully immerse the user in a task that’s intuitive to complete whilst still being not as invasive of special awareness as virtual reality, as a result this adds up to a system that is only limited to the possibilities one can imagine and if executed correctly can be the corner stone for the future of learning and entertainment

# 3.Requirement specifications:

Based on the information above it is evident that the requirements for this project are as follows:

* The application must perform in recognising components as the targets and track them effectively
* 3D objects must be rendered over the targets once they are recognised
* The application must provide a description of the pins on an Arduino
* The application must recognise when two or more targets are in view and recommend code that would make them work with each other.
* specific 3D models must be equipped with animations that run to show the user the outcome of the code recommended
* the application must be able to simulate the connecting of wires from the Arduino to any of the components

For augmented reality to take place the most important requirement the application must complete is the recognition and tracking of the targets to for the system to be able to augment data over them, when coupled with the 3D models and animations as well as the various tools and additional features the application provides to be able to provide an effective learning experience for the user. The features the application should provide are to display information regarding the pins on the Arduino when the augmented mins are tapped as well as recognise when two or more targets are in view and recommend relevant code which is relevant to the Arduino and the component found for the user to examine. Once the code is recommended the application must execute an animation on the 3D model augmented on the component to show the user the eventual outcome of the code recommended. A tool implemented for better simulation of robotic system was the wire creator, this tool can be selected at any time for the user to select a pin on the Arduino and draw a line from the Arduino to any component.

# 4.Analysis and Design:

The design of the application began with the thought on how to construct an application that would be interesting for students in the field to use as it would feel like a novel technology whilst being versatile enough for a lecturer to be able to construct a lecture around it. The first thing needed that needed to be decided was the Augmented reality tool which would be used alongside unity to allow for augmented reality capabilities. There were many tools researched some of which being ARtoolkit, ARcore and wikitude but each of these were either not up to par with vuforia or were too constricting with their trial versions. Vuforia was also chosen due to its stock integration with unity and the wide community it provides. Since vuforia was going to be used the targets had to be registered online and downloaded as unity package, this was done for 2D images for the reason that none of the augmented reality toolkits researched were sophisticated enough or did not match the requirements needed. The 2D targets were registered by taking photos of the desired objects and uploading them to a database on the vuforia website where they would be processed and converted to image targets, the database is then downloaded as unity package to be integrated within unity. Once the targets were inputted into the unity engine the next phase of the design was to find a way of representing the components digitally. What was noticed was that all the components, serve a single output function which could be used in the form of a 3D model to represent the component, these output functions being how a buzzer makes sound, a servo rotates a bit and a solenoid pushes a piston.

The way the components were represented by their characteristics was through the 3D models shown once the target is recognised these being a servo bit, a solenoid piston and a 3D model of the speaker symbol to represent the sound that a buzzer makes, as for the Arduino a pill shaped and coloured 3D model needed to be designed to be augmented over every pin on the Arduino. The system needed a way to display information regarding these pins to the user and this was done by placing invisible buttons in front of the augmented pins so that the user could trigger a side panel with the information in it. Through these details the lecturer can allow the students to familiarise themselves with the different types of pins and what they are used for.

From the point when the Arduino is detected onwards the user can then choose to detect any of the other components, these should show their own individual 3D models that are mentioned above augmented over them upon detection, once any other component is detected alongside the Arduino, the system needs to recommend code to the user related to making the component function where the user may skim through it and attempt to understand with the help of a lecturer, this needs to be done when the application recognises two or more targets one of which being the Arduino and displays a panel showing the code. On this panel the user can find a compile and run button which enables an animation showing the result of the code were it to be run in the Arduino IDE.

Once two or more targets have been selected the user can have the ability to select the create wire button, this was implemented do that the user can have a more in depth simulation of a robotic architecture, this button is where the user is prompted to select the augmented pin on the Arduino target where then the pin selected will show on the left side of the screen to show the user that the pin has been successfully selected where then the user can draw a line by dragging his/her finger on the screen to the desired cube representation of the component’s wire. Once the line has successfully hit the cube a line should be drawn from the pin selected to that cube which represents a wire being connected correctly. Once the wire button is tapped again the ability to draw a new wire is deactivated but the wire drawn can remain whilst constantly updating with the positioning relative to the Arduino and component connected.

The design of the system was constructed in a way to enable the user to explore the different above-mentioned elements to create an intuitive and interesting experience which will allow for a better, more solid understanding of the basic concepts of robotics which will eventually help when faced with working with the components first hand.

## 4.1Flow of the program

The flow of application allows the user to have a lot of intentional freedom so that a lecturer would be able to construct a lecture around the usage of the application, whilst this is true the application does have underlying requirements that need to be completed for the user to get results from the system. Once the user opens the application the first thing seen is the camera view where the user is now free to detect any of four components being the Arduino Uno, a servo, a solenoid, and a buzzer. Once these components are detected the user will see corresponding virtual data augmented over them in the form of 3D models, in reality none of the three component targets would work without the Arduino Uno, so even in the application, both the Arduino target and any of the other three targets need to be detected for the application to recommend the code for that particular component to work and allow the user to compile and run that code to view the results of that code. The user also has the freedom to read details on the pins of the Arduino by tapping the augmented pins on the Arduino. Once there are two or more targets detected as long as one of them is the Arduino the user can draw a wire from any pin on the Arduino to the wires of the other component targets, due to the infinite orientations of a wire these are not tracked but are represented by accordingly coloured cubes for the connecting of wires. This flow process is described visually through the use case diagram in figure 1 below.

# A close up of a map Description generated with high confidence

Figure 1

# 5.Implementation and Testing:

The implementation and execution of the design planned for the thesis was to be with a diverse array of technologies being unity for the construction of the application and used for all the tools and libraries it provides as well as it’s exceptional compatibility with vuforia which was used for its good tracking and recognition algorythm with 2D image targets, community and being well documented. The additional classes and components for the application to be used within unity were made in C-sharp.

## 5.1. Targets and Models

After the targets, which can be seen in figure 2, 3, 4, 5 were registered and inserted within the scene the pins which are augmented over the Arduino were the first to be created and were made in Maya in six different colours for the six different types of pins found on an Arduino board, these can be seen in figure 6.

A circuit board

Description generated with very high confidence

Figure 2

A close up of a device

Description generated with high confidenceA close up of a device

Description generated with high confidence

Figure 4

Figure 3

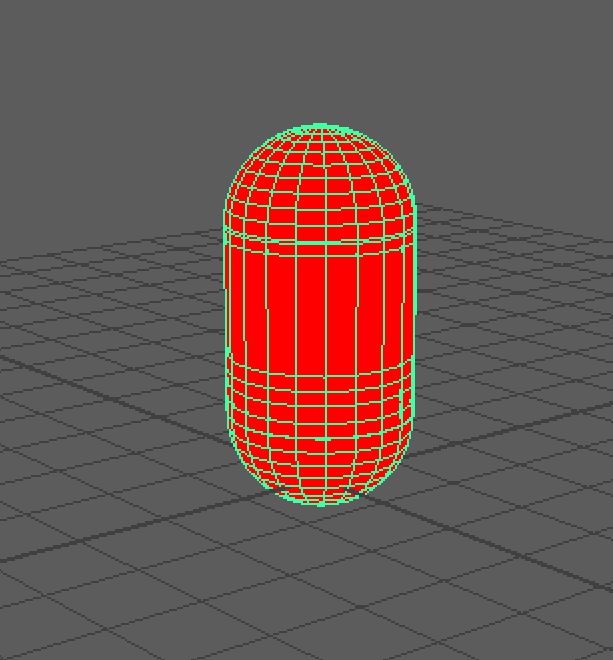


Figure 6

A close up of a device

Description generated with high confidence

Figure 5

After they were created and imported into unity the next step was to show the user what the colours meant and what pins they represented, this was tackled by attaching a text mesh renderer in unity to the model which is a component used to display text over the mesh of the object, the different models were labelled accordingly to represent the pin at which they were positioned at, this can be seen in figure 7, when then the problem arose as to the text not being visible from certain angles where the camera would be pointed at. The solution to this problem was to construct a component using C-sharp to be attached to the models to make them actively change their X and Y rotation based on where the camera was in space, this was done through transforming the rotation of the object the script was attached to the grabbed direction the camera was facing as well as y angle the camera was looking.

A close up of a sign

Description generated with high confidence

Figure 7

Once the models were positioned and labelled with the script attached to look at the camera the next step was to construct a way to show the user different information regarding the different pins on the Arduino and thus the augmented pins had to be made clickable. The first method tried to accomplish this was by using colliders around the augmented pins but due to the screen to world difference being a fixed number and the target and along with them models being constantly moving objects this did not work, the issue was eventually fixed by using UI buttons and setting their material to UI Mask thus effectively making them invisible, the reason this worked is because UI buttons are clicked by using ray casting which meant it didn’t matter their distance from the camera, using these invisible buttons the user now had a way to trigger a side panel that could display different information regarding the specific pin that the user has clicked on this can be seen in figure 8. The next step was to design the 3D models for the other targets, these models as mentioned above had to be an accurate representation of the output of these components, thus an essential piece of these components needed to be modelled. These models were created within Maya and can be seen in figures 9, 10, and 11.

A circuit board

Description generated with high confidence

Figure 8

A picture containing building

Description generated with high confidence

Figure 9

A picture containing floor, indoor, sitting, ground

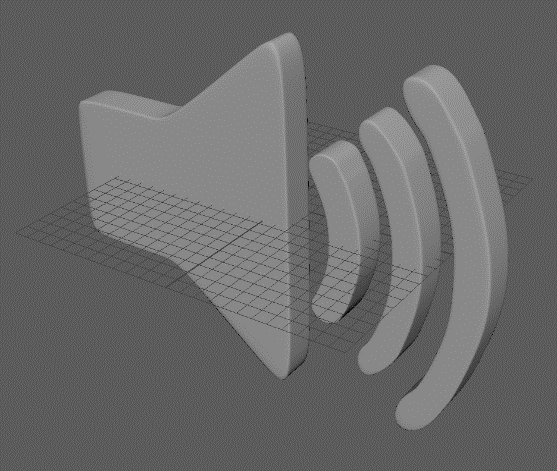
Description generated with high confidenceOnce these models were created and imported into Unity they had to be attached to their corresponding targets in the correct position of the component. These models then had to be equipped with animations to simulate their basic functions to be demonstrated to the user, this was done through the unity animation window where then multiple animations were put together through the unity animator and had to be a direct representation of the code that would be shown. To do this the animations used had to show a starting position, transitioning and the end state, these were all decided based on the code to be shown to the user and the process can be seen in figure 12.

Figure 11

Figure 10

A picture containing building

Description generated with very high confidence

Figure 12

## 5.2. additional features

### 5.2.1 recommending code

Once the animations were created fully there needed to be implemented a trigger for the animation of each of the targets to start specifically when the user had a specific target within view as well as show the user the code of the resulting animation for that specific target. This was fixed by writing a C-sharp script which uses the vuforia library. In this script a StateManager was used to return to the script the active and tracked targets at that moment continuously where then the script checked if one of the targets detected was the Arduino and then which other component was being tracked. Depending on the two objects being tracked the script then makes a panel at the bottom of the screen, housing a text field and a button, active and sets the corresponding code to be written within the text field, this can be seen in figure 13, 14 and 15. Once the user has skimmed through the code and wishes to view the outcome of the code were it to be run on a powered Arduino he/she can tap on the “compile and run” button where a script that grabs the target detected other than the Arduino and find its corresponding animation which it then executes. In this way the user may view the code for different components and see the real-world outcomes without having the risk of connecting the Arduino as well as the components to electricity.

A circuit board

Description generated with very high confidence

Figure 13

A close up of a device

Description generated with high confidence

Figure 14

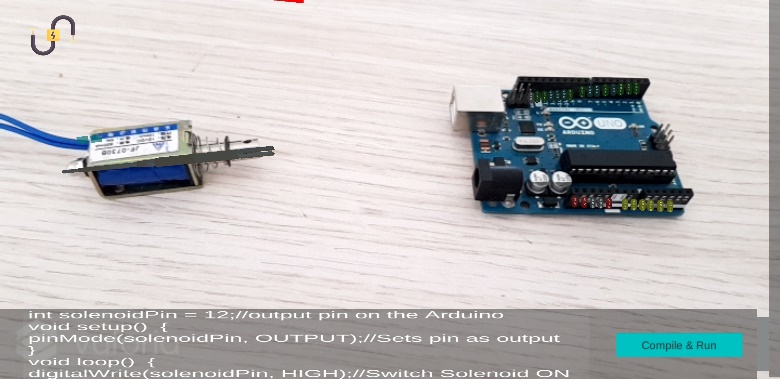


Figure 15

### 5.2.2 Wire Creation Tool

The final feature that was implemented into the application is the wire creation tool, this feature is used to create an augmented wire between the Arduino and any of the other targets, this feature was created to further increase the accuracy of the simulation. The first thing that needed to be completed was the line that would be drawn when the user dragged his/ her finger across the screen when this mode is activated, the way this was done was through creating a c-sharp script which began by constantly checking if the user had touched the screen, if this condition was met a Vector3 variable would be set to the X and Y coordinates of the point where the person has tapped where then the Z position is set to position of the selected pin added to the difference between the screen to world point, which is the difference of distance between the screen to the game world, at this point a white cylinder is instantiated at the point where the user has placed his/her finger, an identical Vector3 variable is created and set after this is done. From this point onwards the second variable is allowed to be changed to the point where the users finger is at while it is on the screen. The script also constantly checks if the first and second variable are the same, if they are not, which means the user’s finger has moved while down on the screen, the first Vector3 variable is subtracted from the second variable to find the distance between the two. Using this distance the cylinder is rotated, moved and stretched to the distance between the two points to create a line when the user holds down a finger to the screen and moves it. The result of the above explanation can be seen in figure 16.

A close up of a device

Description generated with very high confidence

Figure 6

The Script is also set to detect when the user has removed his/her finger from the screen, when this happens the script checks what pin the user has selected and searches for the object by its tag, the script also checks wether the collider attached to the white line drawn by the user has hit any of the colliders attached to the cube representation of wires of the component currently being tracked. Once the Game Object of the pin selected is found and the collider of the line is hit the script grabs the object that hit the line and draws a line using a Line Renderer from the pin selected to the wire of the component being tracked where then the line drawn by the user is destroyed, the result of this process can be seen in figure 17.

A circuit board

Description generated with very high confidence

Figure 17

Once the line is drawn the script saves the line renderer as well as the object it starts at and the object it finishes at into a new class object which is saved in a list for every wire successfully connected by the user. From this point onwards, a separate script is used to grab the list of the class objects containing the line renderer and starting and ending objects, with this list the script grabs the starting and ending objects and checks their new position in space for every class object in the list in an endless loop. Once the new positions are found, the line renderer in the class object currently being addressed is re-drawn with the same width and points to the two newly found positions of the two objects. This process allows the wire to move with the objects its connected to in real time after it has been connected and can be seen in figure 18.

A circuit board

Description generated with high confidence

Figure 18

Through the development of this application a lecturer can effectively deliver material to students without having to compromise on letting the students handle actual equipment whilst helping them to strengthen their understanding of robotic system and allowing the students to learn further on their own.

# 6.Evaluation

Throughout the trial for this project 14 students were asked to use the application and take a TAM test on the usability of the software. The students needed to have some background in computing and needed to go through the application thoroughly to give feedback onto whether it is a useful tool for schools. The students evaluated were taken from a diverse range of age groups as can be seen in figure 19 but were taken from two levels of knowledge on computer studies and robotics. The two groups were 2nd year undergraduates which do have a robotics background and 3rd year undergraduates who have a more in depth and extensive knowledge on robotic architectures as well as having a greater range of experience with diverse robotic components and frameworks. The percentage of the two groups can be seen in figure 20.

A screenshot of a cell phone

Description generated with very high confidence

Figure 19

A screenshot of a cell phone

Description generated with high confidence

Figure 0

## 6.1. Questions Asked

The students were asked an array of question related an array of conditions that the application would need to meet to be an effective learning tool as well as to be accepted as a new technology by students and lecturers in the classroom. As one can see in the figures below the students were asked questions on their opinion on the application’s ability to help teach robotics in an effective way as well as if they thought it would be a good tool to help students in entry level robotics with the first steps in the field.

A close up of text on a white background

Description generated with high confidence

Figure 21 ~ enabled me to better my understanding of robotics

A close up of text on a white background

Description generated with high confidenceA close up of text on a white background

Description generated with very high confidence

Figure 23 ~ The application promoted me to further expand my knowledge in robotics.

Figure 22 ~ I feel this technology would help beginners in robotics

The above figures prove that students find the application useful in teaching robotics and felt that with the help of the application students within entry level robotics can have a better experience and may entice them to further their knowledge in the field. The students were also asked on the overall performance of the application and how intuitive and easy to use the application was. In the figures below, one can see their responses.

A close up of text on a white background

Description generated with high confidence

Figure 24 ~ I was able to use the technology without supervision

A screenshot of a cell phone

Description generated with high confidenceA close up of a logo

Description generated with high confidence

Figure 26 ~ The feedback from interacting with the system was intuitive

Figure 25 ~ The process of using this application was enjoyable

In figures 24, 25 and 26 one can see that there was a generally positive feedback to the overall intuitiveness of the application as well as making the user feel comfortable using the application. The overall feedback regarding the user being able to use the application without supervision or without being told what was required of them was across the spectrum, however, the application is meant to be used in the classroom where students would have a lecturer to oversee their progress with the application, thus as long as the students who needed to be told what was required to be done understood and could continue independently, the application has still met its general usability condition.

The students tested were also asked on their opinions on wither the application should be implemented and used regularly in schools and universities as well as wether they look forward to using technology such as this in the future. The following figures are their responses.

A close up of text on a white background

Description generated with high confidenceA screenshot of a cell phone

Description generated with high confidence

Figure 27 ~ The application should be used regularly

Figure 28 ~ I look forward to using the same technology in the near future

A close up of text on a white background

Description generated with very high confidence

Figure 29 ~ the application should be used by multiple universities

The results above show that the students feel like more technology such as this should be implemented into universities and lectures. These results prove the application can be a useful tool in helping students learn robotics in a more solid and intuitive way as well as push more students to enter the field in the future. These findings can be further shown by the comments that some of the tested students left which can be seen in figure 30.

A screenshot of a cell phone

Description generated with very high confidence

Figure 0

# 7.Conclusion

The application was designed to be an intuitive and interesting way for students to learn and further expand their knowledge in the field of robotics, through the development of the app there were challenges that needed to be overcome to achieve the final version of the application which through rigorous testing met all of premeditated conditions to be an effective method of teaching the subject.

# 8.Future Work

The work planned for the future of this application is evidently for the user to be able to do even more than they are able to do now with the material being delivered through the app. These improvements would consist of changeable variables in the code where the animations would correspond accordingly as well as the condition that a successful and correct connection be made between the component being tracked and the Arduino for the code to able to be shown to the user. Finally, the future of this app lies with being connected to an Arduino IDE plugin for students to be able to directly influence the recommended code from the application and then be able to import it into the IDE for further work and integration with other systems being worked on.

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